

Fig. 8 is a schematic block diagram of an exemplary embodiment of a nonreciprocal phase shifter that includes a plurality of Faraday rotators and half-wave retarders;

Fig. 9 is a graph showing the required waveguide core diameter to limit the diffraction loss to 0.25dB and 0.5dB, respectively, when the thickness of the Faraday rotator is 0.5mm;

5 Fig. 10 is a functional block diagram of an exemplary embodiment of a nonreciprocal phase shifter;

Figs. 11A and 11B are

~~Fig. 11~~ is a schematic block diagram of 4-port circulator based on a Mach-Zehnder polarization splitter and nonreciprocal polarization converter in accordance with the invention; and

Figs. 12A and 12B are

~~Fig. 12~~ is a schematic diagram of backward and forward propagation of an optical signal in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

15 Figs. 4A-4C are schematic block diagrams of exemplary embodiments of polarization independent 2-port (400), 3-port (410), and 4-port (420) isolators/circulators based on a nonreciprocal phase shifter in accordance with the invention. The isolators/circulators include input and output ports, an interferometer, and a polarization-independent nonreciprocal phase shifter (430). The input and output have either one or two ports to make the device an isolator (400), a 3-port circulator (410), or a 4-port circulator (420). The interferometers consist of two
20 couplers (440, 450) and two optical paths in between.

The first coupler (440) divides the intensity of the incoming optical signal evenly into the two arms of the interferometer. The two resulting optical signals undergo different phase